be commended for the clearness with which physical principles are stated, and for the numerous workable and practical problems. That part of the text dealing with lenses and with problems concerning the eye is especially to be commended.

One feature of the text which distinguishes it from others is the grouping together of descriptions of demonstration experiments at the end of each chapter. This is a matter of considerable convenience to an instructor and should prove interesting to a student. Another commendable feature is the large number of references to, or quotations from, other texts or original articles.

The author apparently has not attempted to condense as great a number of facts and principles as possible into the text, but has attempted to present in an interesting form what appears to him to be of most importance, and he has succeeded. As a piece of bookmaking the text is excellent.

G. F. HULL

DARTMOUTH COLLEGE

SPECIAL ARTICLES

THE NUTRITIVE VALUE OF THE PROTEINS OF MAIZE[1]

THE state of knowledge at present prevailing concerning the nutritive value of cornmeal when fed to domestic animals is clearly presented in a letter which I recently received from Professor Willard, of the Kansas Agricultural College, who has had a wide experience with practical feeding experiments made on a large scale on domestic animals. He says:

> It is a matter of common experience extending over many years, that corn appears to be deficient in some particular in nutritive value. Some have thought to account for this on the basis of low protein content; others have attributed the result to its small percentage of ash; still others have taken into account not only the small percentage of ash, but its unbalanced character, being deficient in calcium and possessing a large percentage of magnesium; still more recently there has appeared the possibility that the defect may find an explanation in limitations in the amino-acid components present in the corn protein.

From this quotation it is evident that further study is needed in respect to the relative nutritive value of the constituents of this seed. Professor Mendel and I have recently obtained preliminary results from feeding maize proteins to white rats under conditions similar to those which I described at our fall meeting last year.

The proteins of maize have not received the attention that their great economic importance demands, for these, the most valuable constituents of this seed, form from eight to ten per cent. of a crop which in this country alone is annually worth one and a half billion dollars. This is the more remarkable as those chemical investigations which have been made show that at least one half of the protein of this seed consists of a type possessing such unique chemical and physical characters as to make it probable that its nutritive properties differ to a marked extent from those of the proteins in other foods of either vegetable or animal origin.

In addition to this protein, known as zein, the maize kernel contains small quantities of globulins, albumins and proteoses and also protein substance insoluble in neutral solvents which can be extracted from this seed only by dilute alkalies. This latter protein has been named maize glutelin. According to such data as are at present available, zein forms about 58 per cent. of the proteins of corn, the globulins, albumins, and proteoses together about 6 per cent., and the remaining 36 per cent. is supposed to be maize glutelin.

The few recorded attempts to determine the nutritive value of maize proteins, in the isolated state, have been made only with zein. The conditions under which these have been conducted have been such as to render the results of uncertain value, although in every instance zein, when supplied as the only protein, proved ineffective for maintaining adult animals or promoting the growth of the young.

Zein presents striking differences in its amino-acid make-up when compared with the other proteins commonly present in foods. The greatest interest has centered about the

[1] Read before the National Academy, November 13, 1912.

entire absence of tryptophane and lysine, for feeding experiments with zein were expected to shed light on the important question of amino-acid synthesis by the animal.

Maize glutelin, in contrast to zein, yields all of the amino-acids commonly found in proteins and in proportions corresponding to those yielded by the majority of animal or vegetable proteins.

The globulins, albumins, and proteoses occur in such small quantities that it has not been possible to obtain them in sufficient amount to determine their amino-acid make-up, or their value in nutrition.

and food intake, broken line, of several rats fed on our protein-free milk diet.[2] During period 2 all of these rats had a diet containing zein as its sole protein and, as you will note, they rapidly declined in weight, although the food intake remained nearly constant, or was even increased, as shown by rats 617 and 647. That this quantity of food was sufficient for maintenance is shown by rats 628 and 659, which regained part of their lost weight on an even smaller quantity of food after the zein had been replaced by gliadin. The increased food intake when zein was replaced by casein, edestin or lactalbumin is largely to be ascribed

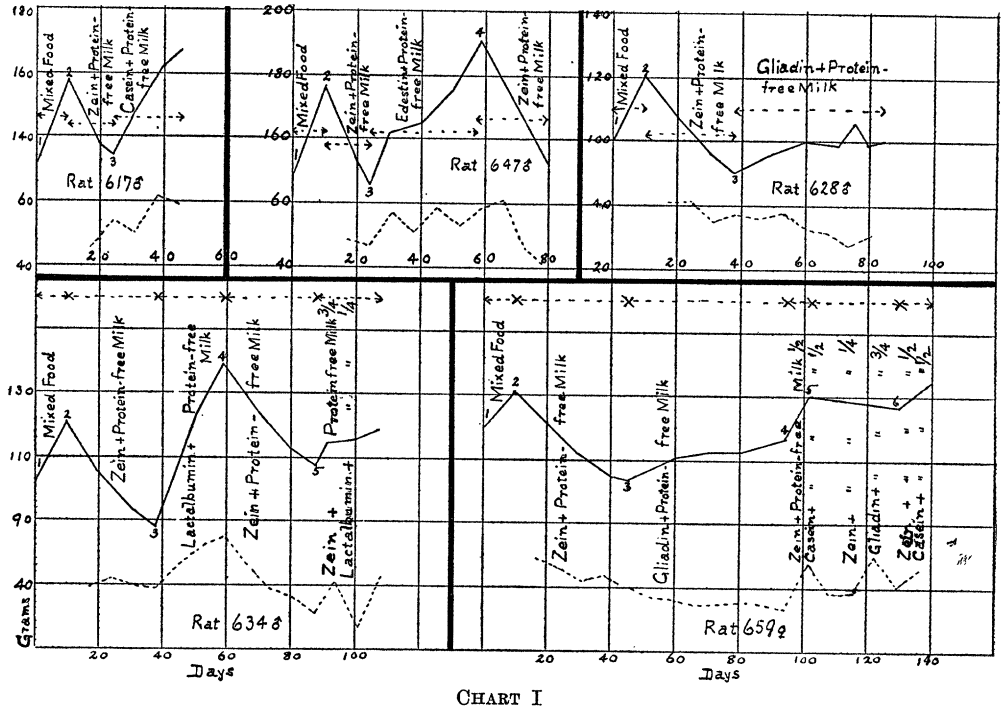

CHART I

Last fall the results of two experiments with mature rats supplied with food containing zein as its sole protein were described. In both cases the animals declined rapidly in weight, although their food intake remained practically constant. These results have since been confirmed by a large number of experiments, some of which are illustrated by the following charts.

Chart I. shows the body weight, solid line,

to the rapid gain in weight which took place when this change was made in the ration. It might be thought that a failure to digest and assimilate zein was the cause of the decline on the zein diet, but curves which you will see later show that can not be so, for the addition of a small amount of tryptophane renders the

[2] SCIENCE, N. S., Vol. XXXIV., No. 882, pp. 722–733, November 24, 1911.

zein food efficient for maintenance over a long period.

Our experiments show that there is a very great difference in the food value of different proteins. Thus we have complete nutritive failure with zein, maintenance with gliadin, and restoration of lost weight, or normal growth, with either casein, lactalbumin or edestin. These three latter proteins yield on hydrolysis both tryptophane and lysine, which zem lacks, whereas bliadin, which is incapable of promoting growth, yields tryptophane, but only a very insignificant proportion of lysine. Gliadin resembles zein in the proportion of amino-acids, other than tryptophane, but differs widely from casein, lactalbumin or edestin.

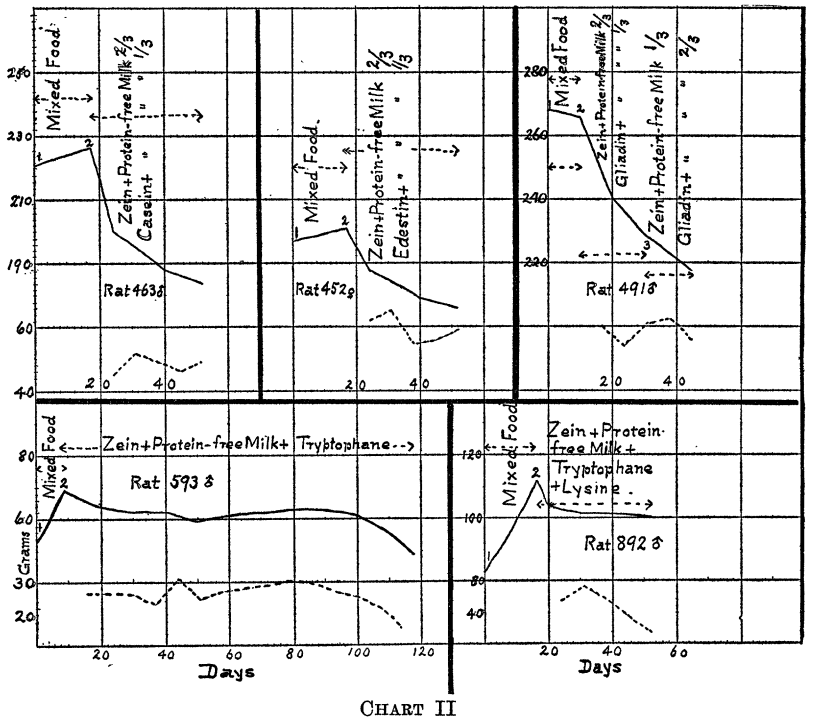

CHART II

Chart II. shows that when a quantity of tryptophane corresponding to 3 per cent. of the protein is added to the zein food, the rat does not decline in weight, but is maintained without growth, just as if fed with gliadin. The curve for rat 892 likewise shows maintenance without growth. This experiment, which is still in progress, indicates that the failure to grow, shown by rat 593, or by rats fed with gliadin, is not due to a lack of lysine in the protein. The fall in weight shown by these two rats at the beginning of the experiment is probably chiefly due to the less bulky experimental food, and the consequent smaller quantity of feces in the digestive tract.

Charts I. and II. show that zein is incapable of maintaining rats, unless tryptophane is added to the diet, whereas on the other proteins, all of which yield tryptophane, they recover their lost weight, and grow at a normal rate except on gliadin. This raises the question whether or not the replacement of a part of the zein by other proteins containing tryptophane will render the ration effective in promoting growth. Unfortunately there is no method known whereby the amount of tryptophane in a protein can be even approximately determined. The nearest approach to an estimate of the relative amount is given by a comparison of the intensity of the color shown by the glyoxylic acid reaction. Such a compari-

son indicates that lactalbumin yields much more tryptophane than edestin, and that edestin yields somewhat more than casein or gliadin, which give reactions of about equal intensity.

We have made some preliminary experiments to determine the effect of replacing a part of the zein with other proteins, but these have not been continued long enough to give final conclusions. The three upper curves show that when one third of the zein is replaced by casein, edestin or gliadin the rat rapidly loses weight. The fall is less rapid and less extensive when one third of the zein is replaced by edestin than when it is replaced by casein.

Chart I., rat 634, shows that when one fourth of the zein is replaced by lactalbumin, weight is regained. Unfortunately this experiment was terminated by death from diseased lungs.

Chart III. shows that rat 633 regained its lost weight very rapidly when one half or one quarter of the zein was replaced by lactalbumin. Rat 487 regained its loss more slowly with one half edestin. Rat 644 was maintained by one half gliadin, and declined rapidly and died when changed to a diet containing one half zein and one half gelatin, a protein which like zein lacks tryptophane.

So far as these results go they agree with the relative intensity of the glyoxylic acid reaction for tryptophane.

Chart IV. shows complete recovery of lost weight when one half of the zein was replaced by casein, and rapid decline when the proportion of casein was reduced to one sixth. This decline was at once stopped when tryptophane was added to the food, the proportion of zein and casein remaining the same. The last period of this experiment was unsatisfactory as the rat soon after died with diseased lungs and kidneys. If disease had not intervened it is not improbable that the lost weight would have been fully regained in period 4.

Chart V. shows a rapid loss of weight when zein formed the sole protein of the diet, and complete recovery when one half of the zein was replaced by casein. After being again reduced on the zein diet, a partial recovery was made when one half of the zein was replaced by edestin, and a nearly complete recovery, when all was replaced by edestin.

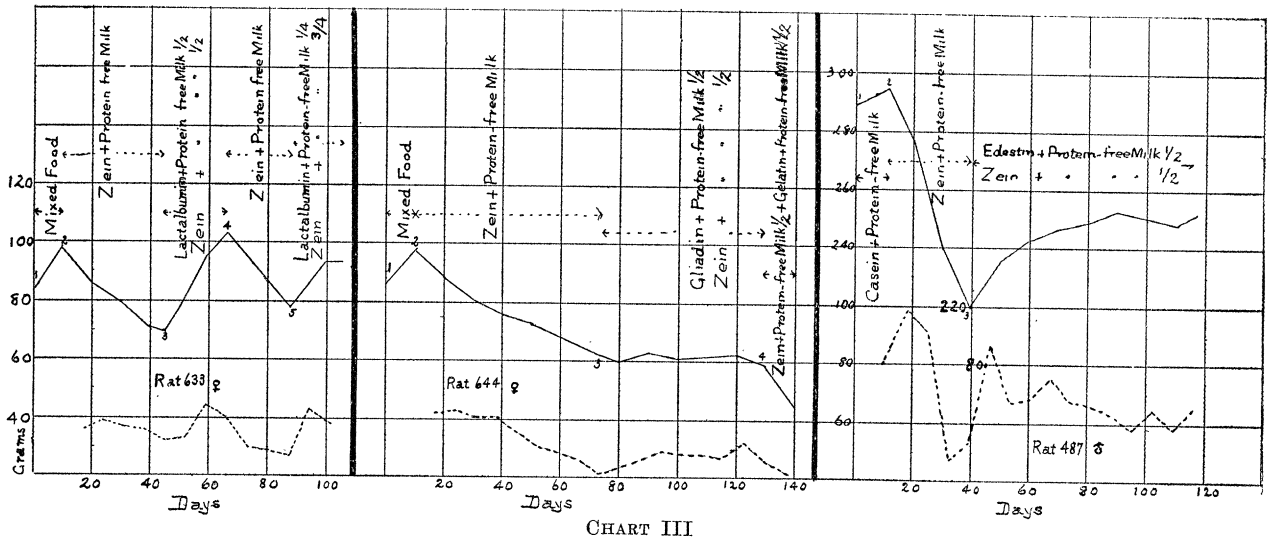

CHART III

It is difficult to understand why diets containing two thirds zein and one third casein or edestin are so inferior to those containing one half of either of these proteins. It may be that experiments now in progress will not confirm these preliminary results, but it is also possible that we shall find that a certain min-

imal quantity of tryptophane is essential for life, and that this is not supplied by these smaller proportions of casein or edestin.

Thus far the experiments I have described have been concerned with zein, which is only one of the proteins of maize.

formed the sole protein. On this diet the rat quadrupled its weight in 70 days, thus exceeding somewhat the average normal rate of growth of rats on natural mixed food. Rat 596 grew more slowly on a diet containing equal parts of zein and maize glutelin.

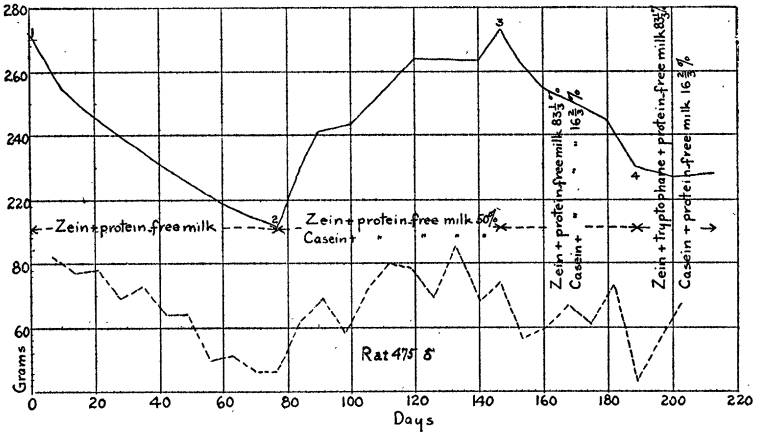

CHART IV

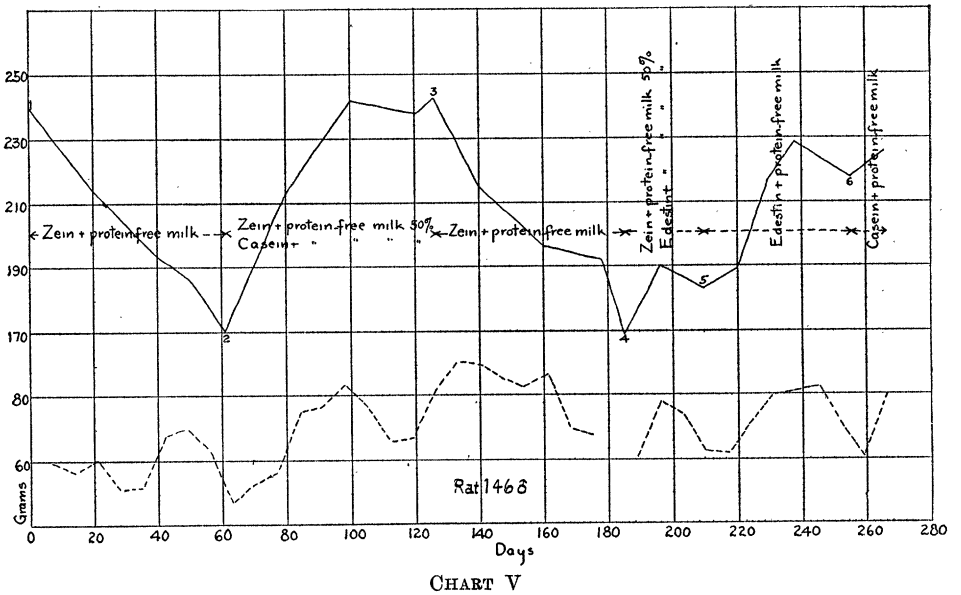

CHART V

Chart VI. shows that corn contains a protein which is capable of promoting normal growth. During period 2, rat 567 was fed with a diet containing the same non-protein constituents as those used in the preceding experiments, but in this food maize glutelin

Chart VII. shows the result of feeding rats with corn gluten. This substance is a product obtained in the manufacture of corn starch, and consists chiefly of zein and maize glutelin, which are separated from the corn by purely mechanical operations. With this

material we have an opportunity to study the nutritive value of the proteins before they have been subjected to the chemical operations incident to their isolation and purification. These curves show that the mixture of proteins in the corn gluten is capable of maintaining

mals. It is interesting to note that the weight lost by these animals was much more quickly regained when one half of the corn gluten was replaced by lactalbumin than by edestin, results which agree with those obtained by adding these proteins to the zein diets.

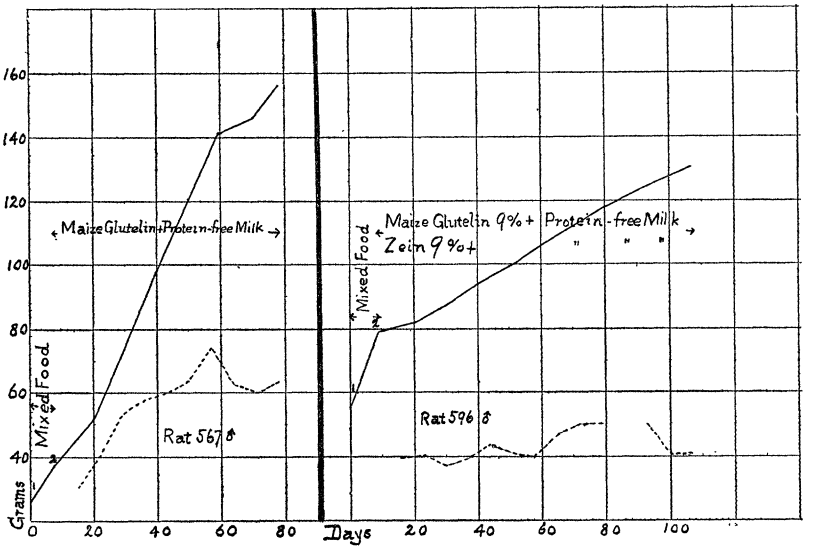

CHART VI

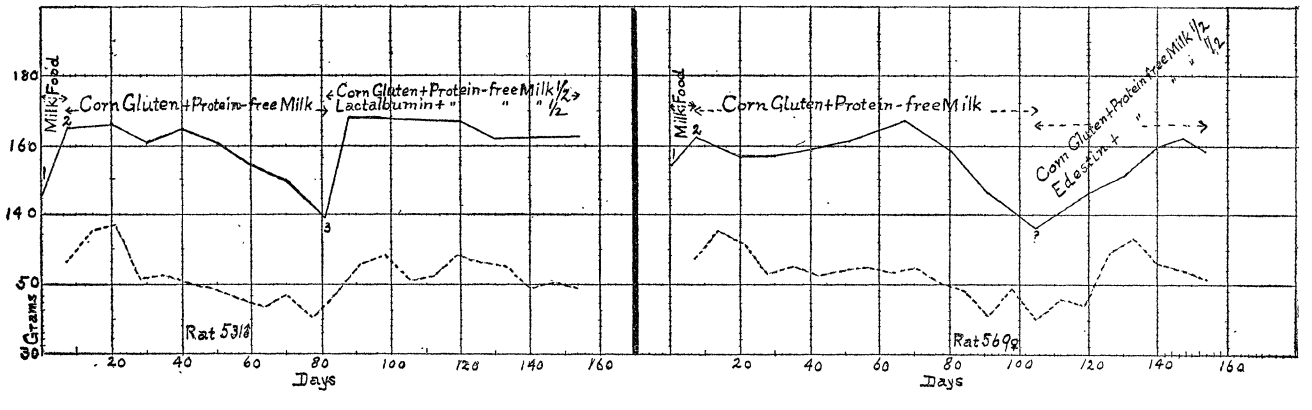

CHART VII

rats for some time. Unfortunately at the time these experiments were started our supply of stock rats was so low we were obliged to use rats which had been previously subjected to long-continued experimental feeding. Doubtless better results will be obtained when we repeat these experiments with fresh ani-

The results here presented leave no doubt that the deficiency observed in the practical feeding of cornmeal is explained largely, if not wholly, by the unique chemical constitution of zein which forms such a large part of its proteins.

Many more experiments must be made be-

fore the numerous questions raised by our feeding trials can be regarded as settled, and attention must finally be given to the relative food value of mixtures of various food stuffs with corn meal, so that we may know as definitely as possible the most economical combinations to employ in maintaining mature animals and in raising the young. Such experiments must be conducted on a large scale and with a variety of domestic animals. In carrying these out the results obtained by the method I have just described when combined with the experience gained in feeding animals for market will doubtless lead to a lower cost of meat production, and at the same time give us information which will contribute to a clearer understanding of some of the obscure problems of the chemical physiology of nutrition.

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DISCOVERY OF BIVALVE CRUSTACEA IN THE COAL MEASURES NEAR PAWTUCKET, R. I.

WHILE collecting fossils for the Museum of Comparative Zoology, Cambridge, from the Carboniferous graphitic slates of Central Falls, Rhode Island, last June, the writer discovered in a half inch layer at two localities one hundred yards apart about two dozen, more or less well preserved impressions of carapaces of bivalve crustacea of the genera *Leaia* and *Estheria,* in the same layer with numerous plant impressions, chiefly leaves of Cordaites and Calamites. No record of their having been previously discovered in the Narragansett Basin Coal Measures was found by the writer, and no specimens of any bivalve crustacea occur in the collection of Coal Measure material from the basin, at Brown University or at Harvard.

The faunal remains from the Narragansett Basin Coal Measures are comparatively meager, and consist largely of tracks which are in many cases of doubtful determination. Previous to the year 1900, fourteen species of insects and one arachnid were identified by Scudder,[1] and the tracks of a probable annelid and of a mollusc or worm were described.[2] In 1900 A. S. Packard[3] described some probable worm tracks, and those of a possible crustacean which were found in some red shale boulders at South Attleboro. He described and named another track found in a pebble of arenaceous shale in a kame in North Providence, and three fragments of a possible macrurous crustacean from the black shales of Valley Falls, R. I., and noted a locality near East Attleboro, shown to him by Professor J. B. Woodworth, where sand-filled worm borings occur in the red and green shales. He also described and identified several casts of valves of a fresh-water mollusc *Anthracomya arenacea* (Dawson) Hind, from a boulder of fine black shale at Valley Falls, and one specimen from a shale bed north of Silver Spring, East Providence.

Numerous supposed amphibian tracks have been found by Professor J. B. Woodworth near Plainville, Mass., and one species, *Batrachichnus plainvillensis,* has been described[4] and named by him. Since then he and the writer have found many types of tracks from several localities near Plainville, and these will probably be described in detail soon. Two or three tracks of probable amphibia were found by Professor Woodworth and the writer last June at Valley Falls and Central Falls, R. I., which is very much south of the localities where they have been previously noted.

From this brief summary of the occurrence of the fossil fauna, it will be seen that only a part of the specimens have been found *in situ,* and the majority of these are tracks. The discovery of these bivalve crustacea in place is therefore of considerable importance.

The impressions of the valves of *Leaia* and *Estheria* occur in a grayish black, somewhat graphitic slate bed along the south bank of the Blackstone River in Central Falls, R. I. The beds strike N. 70°–80° E. about parallel with the river at this place, and dip 70° N.

[1] Bull. U. S. Geol. Survey, No. 101, 1893.

[2] *Proc. Bost. Soc. Nat. Hist.,* XXIV., 1889, pp. 209–216, and *Amer. Jour. Sci.,* 3d Ser., XXXVII., 1889, p. 411.

[3] *Amer. Acad. Arts and Sci. Proc.,* Vol. XXXV., 1900, pp. 399–405.

[4] *Geol. Soc. Am. Bull.,* Vol. IX., 1900, pp. 449–454.